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Impact of organic nutrient strategies for improving growth and yield of cauliflower under protected cultivation

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Abstract

A study was conducted to evaluate the effect of different combinations of organic manures and biofertilizers on the growth and yield of cauliflower in rabi season under naturally ventilated polyhouse conditions. The experiment was carried out during the academic year 2025-26 at the School of Agricultural Sciences, Malla Reddy University, Hyderabad using a Randomized Block Design (RBD) with nine treatments and three replications. The treatments included sole and combined applications of vermicompost, poultry manure, jeevamrutha, lignite and farmyard manure (FYM), along with biofertilizers such as Vesicular Arbuscular Mycorrhiza (VAM), Azospirillum and Phosphate Solubilizing Bacteria (PSB). The results demonstrated significant variation among treatments, highlighting the beneficial effect of integrated organic nutrient management on growth and yield, with T₆ - (Poultry manure 50% (7.5 t ha⁻¹) + VAM (5 kg ha⁻¹) + Azospirillum (2 kg ha⁻¹) + PSB (5 kg ha⁻¹) 50%) consistently exhibited superior performance across all growth and yield parameters.

Keywords: Pusa Snowball-16, organic nutrients, poultry manure, VAM, azospirillum, PSB, protected cultivation

Introduction

Cauliflower (*Brassica oleracea* var. *botrytis*) is a prominent winter-season cole crop with a diploid chromosome number of 2n = 18. It is believed to have originated from *Brassica oleracea* var. *sylvestris* and has evolved through processes such as introgression, mutation and selection. The crop belongs to the family Cruciferae and is cultivated for its edible curd, which is a compact, modified pre-floral apical meristem widely consumed in India (Swarup and Chatterjee, 1972) [10]. Nutritionally, cauliflower is rich in essential nutrients containing about 91.7% water, 4.9 g carbohydrates and 2.4 g protein, along with significant amounts of vitamin C, calcium and phosphorus. It also contains bioactive compounds such as indole-3-carbinol, omega-3 fatty acids and vitamin K, which contribute to its anti-cancer, anti-inflammatory and cardioprotective properties while supporting digestive health (Singh, 1997) [7]. Owing to its mild flavour and versatility, it is widely used in a variety of culinary preparations.

In recent years, organic fertilizers have gained importance due to their synergistic effects with mineral and biological fertilizers, improving soil health and plant growth. (Kalalbandi *et al.*, 2007) [5]. Organic manures such as vermicompost, jeevamrutha, poultry manure, lignite and farmyard manure (FYM) play a significant role in sustainable nutrient management (Bopcha and Agarwal, 2024) [3]. Vermicompost improves soil structure, microbial activity and crop productivity while enhancing produce quality. Jeevamrutha is a fermented organic formulation that enhances microbial activity, improves soil biological properties and crop performance whereas poultry manure is rich in essential nutrients that supports better plant growth and enhances yield in cauliflower. Lignite is rich in organic carbon and humic substances which acts as a carrier for biofertilizers. Farmyard manure (FYM) improves soil fertility, structure and water holding capacity while providing a steady nutrient supply, thereby supporting sustained crop growth and long-term soil health (Bhatt, 2023) [2].

The excessive use of mineral fertilizers in intensive vegetable systems has led to negative impacts on soil and the environment, encouraging the shift toward eco-friendly inputs such as biofertilizers. These improve soil health, reduce costs and enhance sustainability by increasing nitrogen availability and stimulating plant growth through hormone production while also suppressing soilborne pathogens (Asokan *et al.*, 2000). Among them, VAM enhance nutrient and water uptake and improve plant tolerance and productivity, PSB increase phosphorus availability and crop yield whereas Azospirillum promotes root development, nutrient uptake and overall plant growth (Zbar *et al.*, 2021 & Kachari *et al.*, 2009) ^[1, 4, 13].

The combined use of organic manures and biofertilizers within a naturally ventilated polyhouse creates a favourable growing environment that supports enhanced cauliflower growth and yield. The relatively stable microclimatic conditions, including moderated temperature, humidity and air movement, facilitate efficient nutrient availability and uptake while minimizing plant

stress. This leads to improved vegetative development, expressed through greater plant height, increased leaf production, expanded leaf area, wider canopy spread, and enhanced root growth. In contrast, crops grown under open field conditions are frequently exposed to unpredictable environmental variations that can interfere with nutrient efficiency and restrict growth potential. Consequently, integrating organic nutrient sources with polyhouse cultivation offers a more reliable and efficient system for achieving improved growth, productivity and overall crop performance.

Materials and Methods

The experiment was conducted during the academic year 2025-2026 at the School of Agricultural Sciences, Malla Reddy University, Hyderabad. The materials used and the methodology adopted for the present investigation are described in the following sections.

Table 1: Treatment details

Treatments	Combinations	Concentration/ha
T ₁	Vermicompost 100%	5t
T ₂	Poultry manure 100%	15t
T ₃	Jeevamrutha 100%	500L
T ₄	Lignite 100%	1t
T ₅	Vermicompost 50% + VAM + Azospirillum + PSB 50%	2.5t + 5kg + 2kg + 5kg
T ₆	Poultry manure 50% + VAM + Azospirillum + PSB 50%	7.5t + 5kg + 2kg + 5kg
T ₇	Jeevamrutha 50% + VAM + Azospirillum + PSB 50%	250L + 5kg + 2kg + 5kg
T ₈	Lignite 50% + VAM + Azospirillum + PSB 50%	0.5t + 5kg + 2kg + 5kg
T ₉	Control - FYM	25t

Experimental Design

The experiment was conducted following a Randomized Block Design (RBD), a widely used experimental layout in agricultural research due to its ability to control field variability. This design was adopted to minimize the influence of inherent variations such as differences in soil fertility, moisture availability, temperature and other microclimatic factors that can affect plant growth. To achieve this, the experimental field was divided into uniform blocks so that each block provided similar growing conditions. Nine treatments (T₁-T₉) were evaluated, with each treatment appearing once in every block and the experiment was replicated three times, resulting in a total of 27 experimental units. The treatments were randomly allocated within each block to eliminate bias and ensure that the observed differences in crop

performance were solely due to treatment effects rather than positional variation.

The RBD framework thus facilitated the following outcomes:

- Improved experimental accuracy by minimizing variability and reducing error.
- Enabled unbiased and effective comparison among different treatments.
- Provided a sound basis for valid statistical analysis and interpretation
- Enhanced reliability and reproducibility of the experimental results.
- Ensured better representation of treatment effects across varying field conditions



Fig 1: Overall experiment plot

Results and Discussion

Growth parameters, Plant height (cm)

Table 2: Effect of different organic manures and biofertilizers on plant height (cm)

Treatment details		Plant height (cm)		
		30 DAT	45 DAT	60 DAT
T ₁	Vermicompost 100% (5 t ha ⁻¹)	24.43	34.76	44.94
T ₂	Poultry manure 100% (15 t ha ⁻¹)	25.43	35.33	46.49
T ₃	Jeevamrutha 100% (500 l ha ⁻¹)	23.3	32.0	42.62
T ₄	Lignite 100% (1 t ha ⁻¹)	21.36	29.26	39.91
T ₅	Vermicompost 50% (2.5 t ha ⁻¹) + VAM (5 kg ha ⁻¹) + Azospirillum (2 kg ha ⁻¹) + PSB (5 kg ha ⁻¹) 50%	27.56	37.66	49.3
T ₆	Poultry manure 50% (7.5 t ha ⁻¹) + VAM (5 kg ha ⁻¹) + Azospirillum (2 kg ha ⁻¹) + PSB (5 kg ha ⁻¹) 50%	28.13	38.46	50.15
T ₇	Jeevamrutha 50% (250 l ha ⁻¹) + VAM (5 kg ha ⁻¹) + Azospirillum (2 kg ha ⁻¹) + PSB (5 kg ha ⁻¹) 50%	27.3	35.36	46.94
T ₈	Lignite 50% (0.5 MT ha ⁻¹) + VAM (5 kg ha ⁻¹) + Azospirillum (2 kg ha ⁻¹) + PSB (5 kg ha ⁻¹) 50%	22.8	31.6	41.54
T ₉	Control - FYM (25 t ha ⁻¹)	24.06	32.9	43.26
SEm (±)		1.15	1.322	1.552
CD (P=0.05)		3.487	3.999	4.693

Plant height is an important morphological parameter in cauliflower, reflecting the vegetative vigor and overall growth performance of the crop. It was measured from the base of the stem to the tip of the longest leaf at 30, 45, and 60 days after transplanting (DAT). The results indicated significant variation in treatment T₆ (Poultry manure 50% (7.5 t ha⁻¹) + VAM (5 kg ha⁻¹) + Azospirillum (2 kg ha⁻¹) + PSB (5 kg ha⁻¹) 50%) at 30, 45 and 60 DAT respectively, which was on par with T₅ (Vermicompost 50% (2.5 t ha⁻¹) + VAM (5 kg ha⁻¹) + Azospirillum (2 kg ha⁻¹) + PSB (5 kg ha⁻¹) 50%) which recorded 27.56, 37.66 and 49.30 cm. The lowest plant height was recorded in T₄ (Lignite 100% (1 t ha⁻¹)) with values of 21.36,

29.26 and 39.91 cm at the respective stages.

The increased plant height under integrated nutrient treatments can be attributed to the combined influence of organic manures and biofertilizers in enhancing nutrient availability, microbial activity and root development. The superior performance of T₆ is likely due to the synergistic effect of poultry manure, which supplies readily available nutrients, along with Azospirillum (nitrogen fixation), PSB (phosphorus solubilization) and VAM (enhanced nutrient and water uptake). This integrated approach improves nutrient use efficiency and overall plant growth, resulting in greater plant height. Similar results were reported by Kachari *et al.* (2009) and Singh *et al.* (2023)^[4, 8].

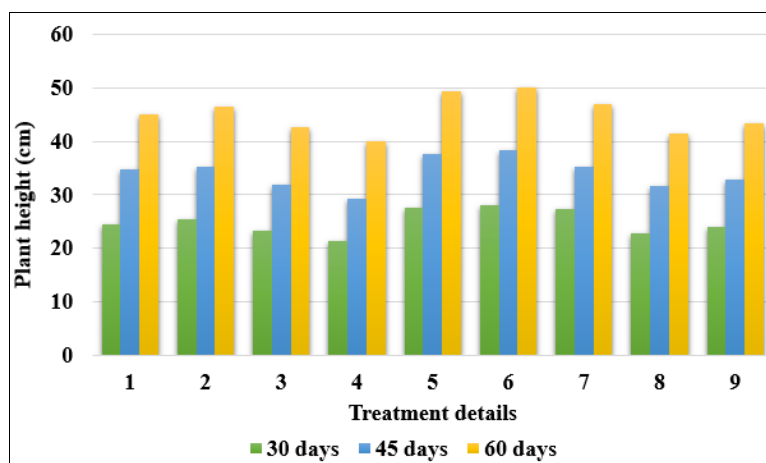


Fig 2: Graphical representation on plant height (cm)

Number of leaves per plant

Table 3: Effect of different organic manures and biofertilizers on number of leaves

Treatment details		Number of leaves		
		30 DAT	45 DAT	60 DAT
T ₁	Vermicompost 100% (5 t ha ⁻¹)	8.63	12.68	18.40
T ₂	Poultry manure 100% (15 t ha ⁻¹)	8.94	12.99	18.46
T ₃	Jeevamrutha 100% (500 l ha ⁻¹)	8.30	12.35	17.55
T ₄	Lignite 100% (1 t ha ⁻¹)	7.70	11.30	16.79
T ₅	Vermicompost 50% (2.5 t ha ⁻¹) + VAM (5 kg ha ⁻¹) + Azospirillum (2 kg ha ⁻¹) + PSB (5 kg ha ⁻¹) 50%	9.31	13.27	19.66
T ₆	Poultry manure 50% (7.5 t ha ⁻¹) + VAM (5 kg ha ⁻¹) + Azospirillum (2 kg ha ⁻¹) + PSB (5 kg ha ⁻¹) 50%	9.63	13.74	19.73
T ₇	Jeevamrutha 50% (250 l ha ⁻¹) + VAM (5 kg ha ⁻¹) + Azospirillum (2 kg ha ⁻¹) + PSB (5 kg ha ⁻¹) 50%	8.98	13.17	18.90
T ₈	Lignite 50% (0.5 MT ha ⁻¹) + VAM (5 kg ha ⁻¹) + Azospirillum (2 kg ha ⁻¹) + PSB (5 kg ha ⁻¹) 50%	7.85	11.44	16.99
T ₉	Control - FYM (25 t ha ⁻¹)	8.44	12.43	18.36
SEm (±)		0.357	0.381	0.373
CD (P=0.05)		1.080	1.152	1.129

A considerable difference was observed in the number of leaves per plant in cauliflower under different organic nutrient management treatments. Significant variation in the number of leaves per plant was observed under different organic nutrient treatments, with observations recorded at 30, 45 and 60 DAT. Among the treatments, T₆ (Poultry manure 50% (7.5 t ha⁻¹) + VAM (5 kg ha⁻¹) + Azospirillum (2 kg ha⁻¹) + PSB (5 kg ha⁻¹) 50%) recorded the highest number of leaves (9.63, 13.74, and 19.73) at 30, 45 and 60 DAT, respectively. This treatment was on par with T₅, which recorded 8.98, 13.17 and 18.90 leaves per plant, while the lowest number of leaves was observed in T₄ (Lignite 100%) with 7.70, 11.30 and 16.79 leaves at the respective stages.

The increased number of leaves per plant in T₆ may be attributed to improved nutrient balance and enhanced physiological activity under integrated nutrient management. The combined application of organic manures and biofertilizers likely created favorable conditions for continuous nutrient supply and efficient utilization, which supported active meristematic growth and leaf initiation. Enhanced metabolic activity and improved photosynthetic efficiency would have further promoted the formation of new leaves and overall vegetative development. In addition, better root growth and nutrient uptake efficiency contributed to sustained plant vigor, resulting in a higher number of leaves per plant (Kachari *et al.*, 2009 & Singh *et al.*, 2023)^[4, 8].

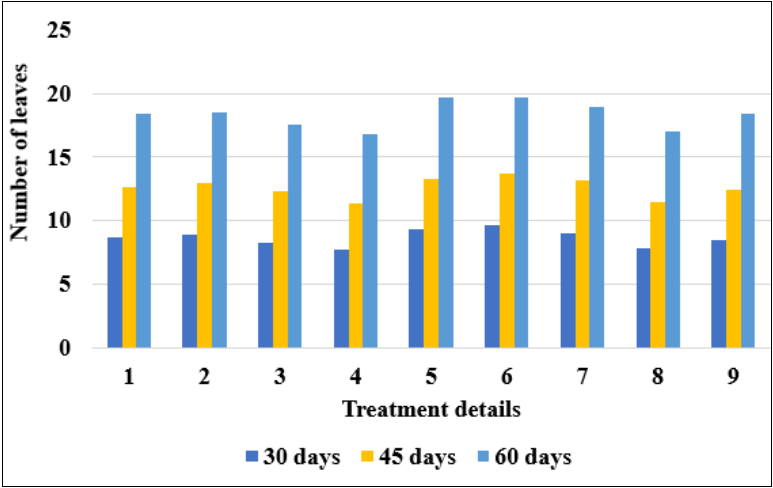


Fig 3: Graphical representation on number of leaves per plant

Leaf length (cm)

Table 4: Effect of different organic manures and biofertilizers on leaf length (cm)

Treatment details		Leaf length (cm)		
		30 DAT	45 DAT	60 DAT
T ₁	Vermicompost 100% (5 t ha ⁻¹)	15.16	22.46	26.43
T ₂	Poultry manure 100% (15 t ha ⁻¹)	15.60	22.66	27.3
T ₃	Jeevamrutha 100% (500 l ha ⁻¹)	13.33	20.70	25.53
T ₄	Lignite 100% (1 t ha ⁻¹)	11.57	18.46	24.44
T ₅	Vermicompost 50% (2.5 t ha ⁻¹) + VAM (5 kg ha ⁻¹) + Azospirillum (2 kg ha ⁻¹) + PSB (5 kg ha ⁻¹) 50%	17.43	23.60	29.51
T ₆	Poultry manure 50% (7.5 t ha ⁻¹) + VAM (5 kg ha ⁻¹) + Azospirillum (2 kg ha ⁻¹) + PSB (5 kg ha ⁻¹) 50%	19.18	24.20	29.54
T ₇	Jeevamrutha 50% (250 l ha ⁻¹) + VAM (5 kg ha ⁻¹) + Azospirillum (2 kg ha ⁻¹) + PSB (5 kg ha ⁻¹) 50%	16.28	23.41	28.35
T ₈	Lignite 50% (0.5 MT ha ⁻¹) + VAM (5 kg ha ⁻¹) + Azospirillum (2 kg ha ⁻¹) + PSB (5 kg ha ⁻¹) 50%	12.47	19.43	25.40
T ₉	Control - FYM (25 t ha ⁻¹)	13.92	21.38	25.97
SEm (±)		1.033	0.47	0.507
CD (P=0.05)		3.124	1.422	1.534

A noticeable variation was observed in leaf length of cauliflower at 30, 45 and 60 DAT under different organic nutrient management practices. Among the treatments, T₆ produced the maximum leaf length with values of 19.18, 24.20 and 29.54 cm which was on par with T₅ (17.43, 23.60 and 29.51 cm), while the lowest values were observed in T₄ (11.57, 18.46 and 24.44 cm). The increased leaf length observed in T₆ may be attributed to the improved nutrient availability and enhanced physiological efficiency resulting from the integrated application of organic manures and biofertilizers. The balanced and continuous supply of nutrients, along with improved soil biological activity likely

promoted active cell division and elongation, leading to greater leaf expansion. In addition, enhanced root growth and nutrient uptake efficiency under integrated nutrient management would have supported better photosynthetic activity and assimilate production. The improved metabolic processes, including chlorophyll synthesis and enzyme activity further contributed to vigorous vegetative growth and increased leaf elongation. These combined effects ultimately resulted in superior leaf development under T₆ compared to other treatments (Sharma *et al.*, 2021 & Kachari *et al.*, 2009)^[4, 6].

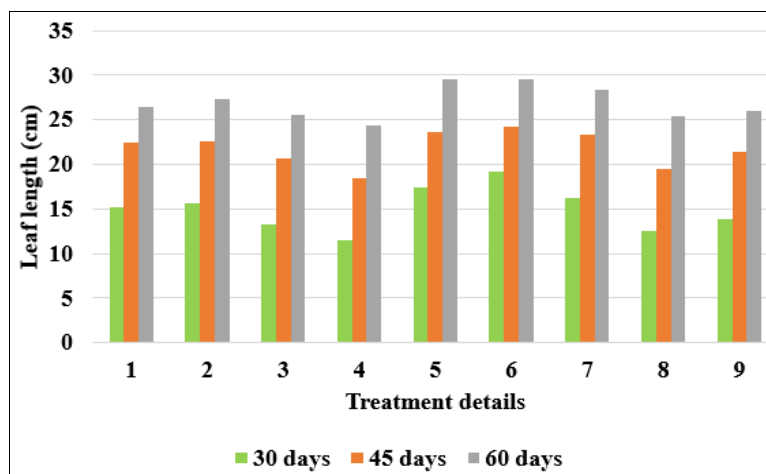


Fig 4: Graphical representation on leaf length (cm)



Fig 5: Measuring leaf length (cm) and leaf width (cm)

Leaf width (cm)

Table 5: Effect of different organic manures and biofertilizers on leaf width (cm)

Treatment details		Leaf width (cm)		
		30 DAT	45 DAT	60 DAT
T ₁	Vermicompost 100% (5 t ha ⁻¹)	15.12	20.86	26.8
T ₂	Poultry manure 100% (15 t ha ⁻¹)	15.75	21.66	27.47
T ₃	Jeevamrutha 100% (500 l ha ⁻¹)	14.46	20.36	25.81
T ₄	Lignite 100% (1 t ha ⁻¹)	12.55	18.69	24.83
T ₅	Vermicompost 50% (2.5 t ha ⁻¹) + VAM (5 kg ha ⁻¹) + Azospirillum (2 kg ha ⁻¹) + PSB (5 kg ha ⁻¹) 50%	17.07	22.34	29.13
T ₆	Poultry manure 50% (7.5 t ha ⁻¹) + VAM (5 kg ha ⁻¹) + Azospirillum (2 kg ha ⁻¹) + PSB (5 kg ha ⁻¹) 50%	17.1	22.82	29.96
T ₇	Jeevamrutha 50% (250 l ha ⁻¹) + VAM (5 kg ha ⁻¹) + Azospirillum (2 kg ha ⁻¹) + PSB (5 kg ha ⁻¹) 50%	16.43	21.95	28.72
T ₈	Lignite 50% (0.5 MT ha ⁻¹) + VAM (5 kg ha ⁻¹) + Azospirillum (2 kg ha ⁻¹) + PSB (5 kg ha ⁻¹) 50%	13.68	19.13	25.66
T ₉	Control - FYM (25 t ha ⁻¹)	14.89	20.79	26.64
SEm (±)		0.547	0.559	0.419
CD (P=0.05)		1.653	1.691	1.266

A significant variation in the width of the longest leaf was observed among different organic nutrient treatments, with measurements recorded at 30, 45 and 60 DAT. Among the treatments, T₆ (Poultry manure 50% (7.5 t ha⁻¹) + VAM (5 kg ha⁻¹) + Azospirillum (2 kg ha⁻¹) + PSB (5 kg ha⁻¹) 50%) recorded the maximum leaf width of 17.10, 22.82, and 29.96 cm which was on par with T₅ (17.07, 22.34 and 29.13 cm) and followed by T₇ with 16.43, 21.95 and 28.72 cm. The lowest leaf width was recorded in T₄ (12.55, 18.69 and 24.83 cm).

The increased leaf width observed in T₆ may be attributed to enhanced nutrient dynamics and improved physiological functioning under integrated nutrient management. The balanced and sustained nutrient supply, coupled with higher microbial activity likely facilitated efficient nutrient mineralization and

uptake, promoting greater cell expansion and leaf enlargement. In addition, improved chlorophyll content and photosynthetic efficiency would have enhanced assimilate production and translocation, supporting broader leaf development. The integration of organic inputs also improves soil structure and moisture retention, creating favorable conditions for root proliferation and nutrient absorption. This enhanced root-shoot interaction, along with increased enzymatic and metabolic activity contributes to improved tissue development and vegetative growth, ultimately resulting in wider leaves. Similar findings were reported by Kachari *et al.* (2009) and Zbar *et al.* (2021) [4, 13], who observed enhanced vegetative growth in cauliflower under integrated nutrient management practices.

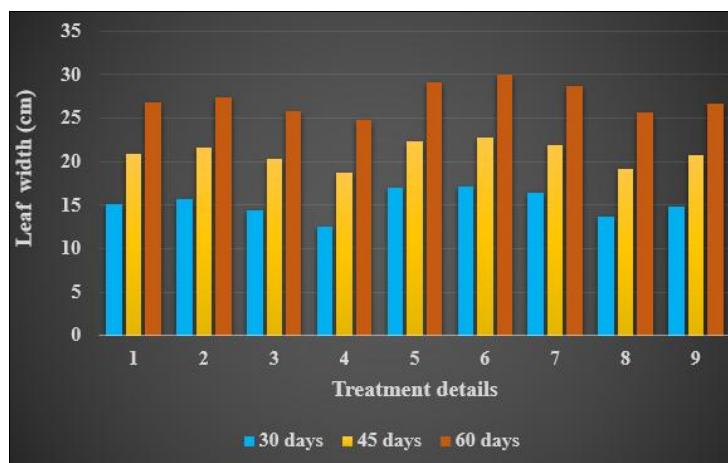


Fig 6: Graphical representation on leaf width (cm)

Plant spread diameter (cm)

Table 6: Effect of different organic manures and biofertilizers on plant spread diameter (cm)

Treatment details		Plant spread diameter (cm)		
		30 DAT	45 DAT	60 DAT
T ₁	Vermicompost 100% (5 t ha ⁻¹)	28.20	41.83	58.68
T ₂	Poultry manure 100% (15 t ha ⁻¹)	28.63	43.89	60.80
T ₃	Jeevamrutha 100% (500 l ha ⁻¹)	22.86	39.51	54.52
T ₄	Lignite 100% (1 t ha ⁻¹)	20.71	35.49	51.53
T ₅	Vermicompost 50% (2.5 t ha ⁻¹) + VAM (5 kg ha ⁻¹) + Azospirillum (2 kg ha ⁻¹) + PSB (5 kg ha ⁻¹) 50%	31.89	46.93	63.02
T ₆	Poultry manure 50% (7.5 t ha ⁻¹) + VAM (5 kg ha ⁻¹) + Azospirillum (2 kg ha ⁻¹) + PSB (5 kg ha ⁻¹) 50%	32.43	48.34	65.56
T ₇	Jeevamrutha 50% (250 l ha ⁻¹) + VAM (5 kg ha ⁻¹) + Azospirillum (2 kg ha ⁻¹) + PSB (5 kg ha ⁻¹) 50%	30.74	46.37	62.49
T ₈	Lignite 50% (0.5 MT ha ⁻¹) + VAM (5 kg ha ⁻¹) + Azospirillum (2 kg ha ⁻¹) + PSB (5 kg ha ⁻¹) 50%	22.16	36.29	52.63
T ₉	Control - FYM (25 t ha ⁻¹)	24.76	41.52	57.40
SEm (±)		0.411	0.439	0.669
CD (P=0.05)		1.244	1.328	1.399

The results revealed significant variation in plant spread among the treatments, with T₆ recording the maximum plant spread of 32.43, 48.34, and 65.56 cm at 30, 45 and 60 DAT which was on par with T₅ (31.89, 46.93 and 63.02 cm) followed by T₇ with values 30.74, 46.37 and 62.49 cm which were statistically comparable while the minimum plant spread was observed in T₄ (20.71, 35.49 and 51.53 cm).

The increased plant spread in T₆ may be attributed to improved nutrient availability and enhanced physiological activity under integrated nutrient management. The combined application of organic manures and biofertilizers likely promoted better root

growth and efficient nutrient absorption, which supported increased leaf expansion and canopy development. Improved soil structure and moisture retention would have further facilitated sustained plant growth, leading to wider canopy spread. In addition, enhanced photosynthetic activity and assimilate distribution may have contributed to vigorous vegetative growth and greater lateral expansion of the plant. These findings are in agreement with Sharma *et al.* (2021) and Singh *et al.* (2013) [6, 9], who reported improved plant spread under integrated nutrient management practices.

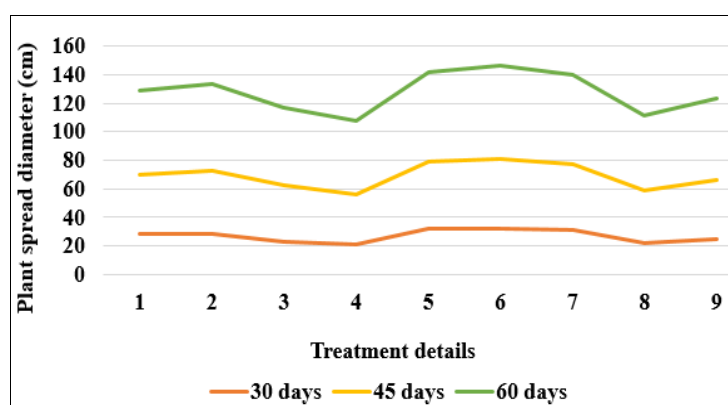


Fig 7: Graphical representation on plant spread diameter (cm)



Fig 8: Measuring of plant height (cm) and plant spread diameter (cm)

Yield parameters, Fresh weight of curd (g)

Table 7: Effect of different organic manures and biofertilizers on fresh wt. of curd (g)

Treatment details		Fresh wt. of curd (g)
T ₁	Vermicompost 100% (5 t ha ⁻¹)	682.81
T ₂	Poultry manure 100% (15 t ha ⁻¹)	730.70
T ₃	Jeevamrutha 100% (500 l ha ⁻¹)	448.57
T ₄	Lignite 100% (1 t ha ⁻¹)	268.85
T ₅	Vermicompost 50% (2.5 t ha ⁻¹) + VAM (5 kg ha ⁻¹) + Azospirillum (2 kg ha ⁻¹) + PSB (5 kg ha ⁻¹) 50%	812.38
T ₆	Poultry manure 50% (7.5 t ha ⁻¹) + VAM (5 kg ha ⁻¹) + Azospirillum (2 kg ha ⁻¹) + PSB (5 kg ha ⁻¹) 50%	825.57
T ₇	Jeevamrutha 50% (250 l ha ⁻¹) + VAM (5 kg ha ⁻¹) + Azospirillum (2 kg ha ⁻¹) + PSB (5 kg ha ⁻¹) 50%	764.50
T ₈	Lignite 50% (0.5 MT ha ⁻¹) + VAM (5 kg ha ⁻¹) + Azospirillum (2 kg ha ⁻¹) + PSB (5 kg ha ⁻¹) 50%	347.23
T ₉	Control - FYM (25 t ha ⁻¹)	581.55
SEm (±)		2.113
CD (P=0.05)		6.390

Fresh curd weight varied markedly across the different treatments, with T₆ Poultry manure 50% (7.5 t ha⁻¹) + VAM (5 kg ha⁻¹) + Azospirillum (2 kg ha⁻¹) + PSB (5 kg ha⁻¹) 50% producing the highest curd weight (825.57 g), which was on par with T₅ (812.38 g), followed by T₇ (764.50 g) and the lowest curd weight was recorded in T₄ (Lignite 100%) with 268.85 g. The superior curd weight under T₆ can be attributed to improved nutrient supply and efficient physiological functioning under integrated nutrient management. The sustained availability of nutrients likely enhanced vegetative growth and photosynthetic capacity, leading to greater synthesis of assimilates. These

photosynthates were effectively translocated towards the developing curd, acting as a strong sink thereby increasing curd size and weight. Additionally, improved root growth and nutrient uptake efficiency may have supported better partitioning of nutrients towards reproductive development. Enhanced biochemical activities, including carbohydrate metabolism and enzyme action, further contributed to curd formation. The combined influence of organic manures and biofertilizers also improves soil health and ensures a steady nutrient release throughout the growth period. These findings are in agreement with Thakur *et al.* (2018)^[11].

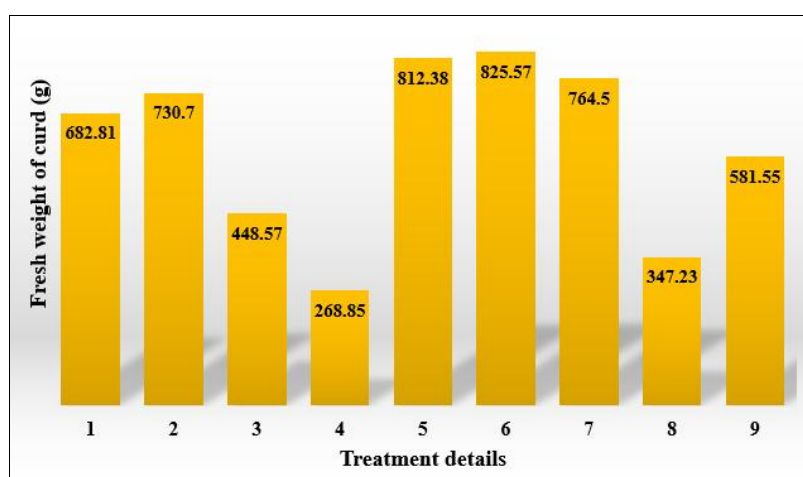


Fig 9: Graphical representation on fresh weight of curd (g)

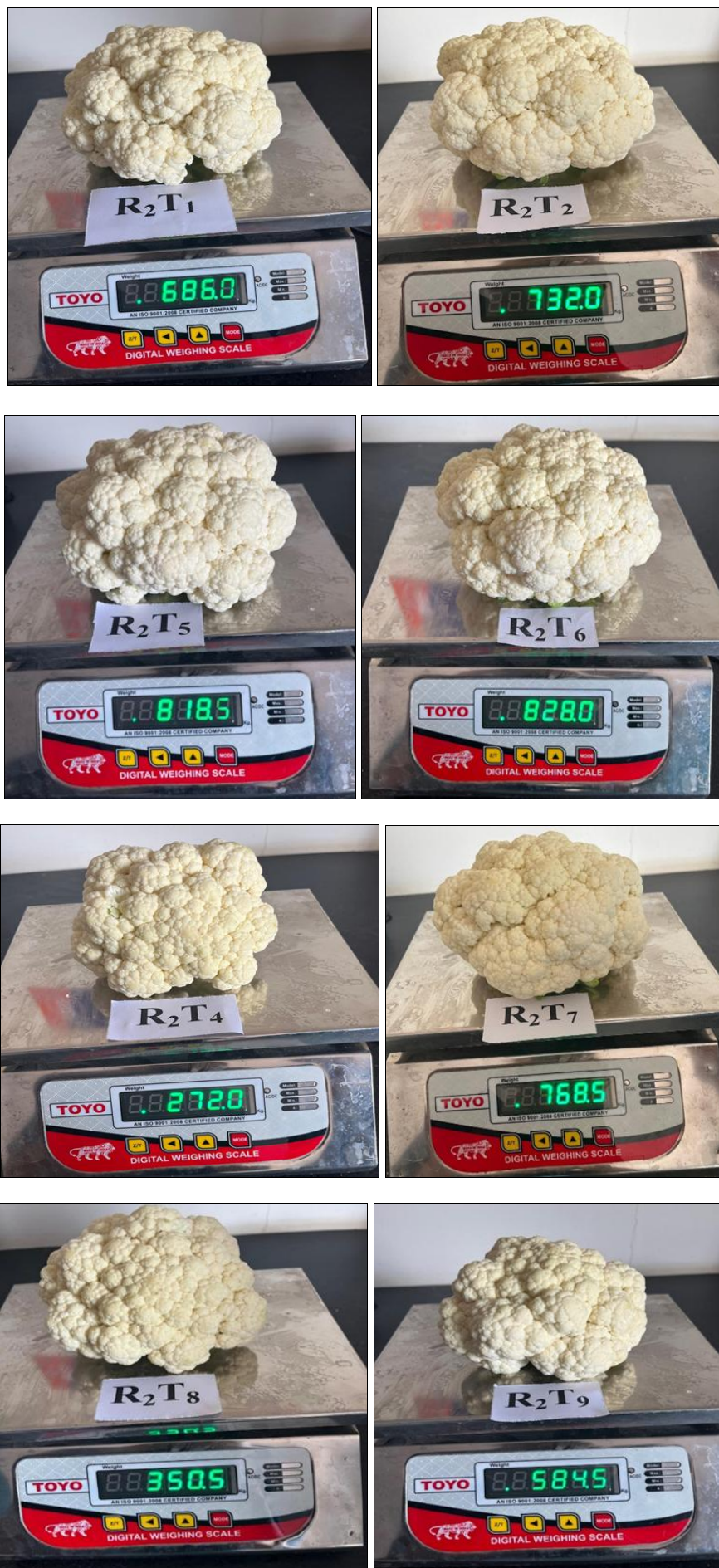


Fig 10: Measuring of fresh weight of curd (g)

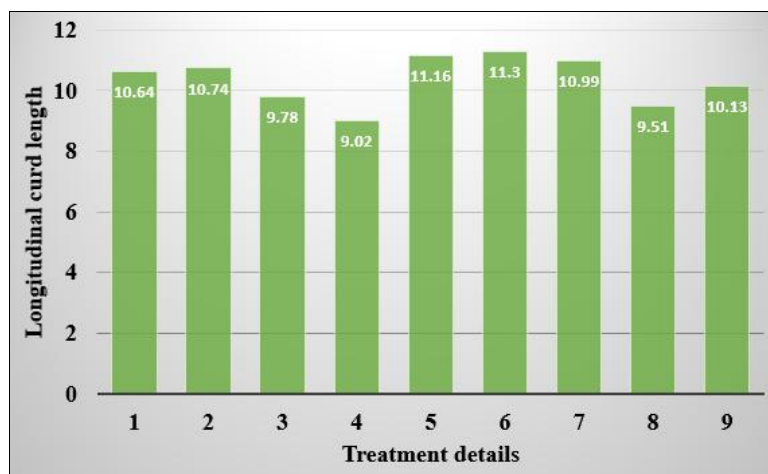
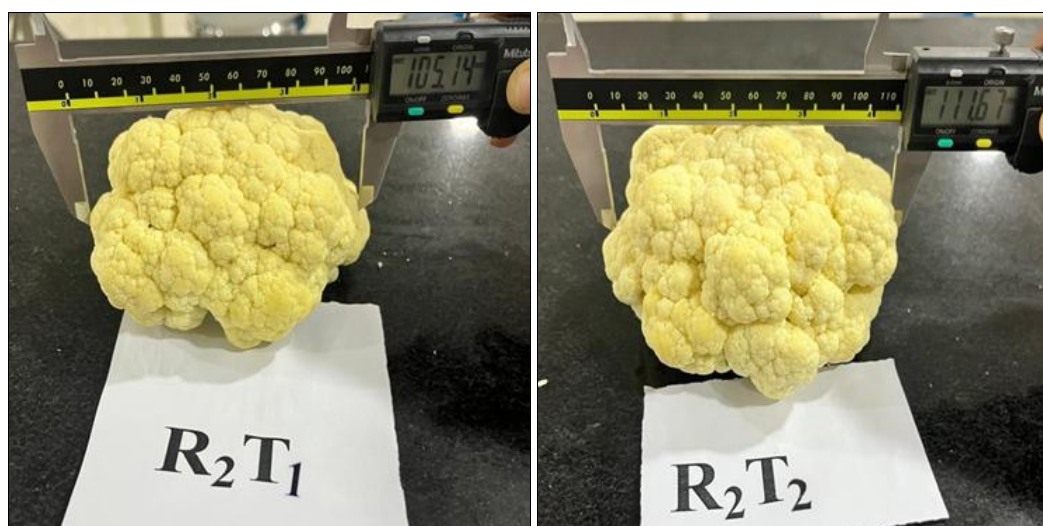
Longitudinal curd length (cm)**Table 8:** Effect of different organic manures and biofertilizers on longitudinal curd length (cm)

	Treatment details	Longitudinal curd length (cm)
T ₁	Vermicompost 100% (5 t ha ⁻¹)	10.64
T ₂	Poultry manure 100% (15 t ha ⁻¹)	10.74
T ₃	Jeevamrutha 100% (500 l ha ⁻¹)	9.78
T ₄	Lignite 100% (1 t ha ⁻¹)	9.02
T ₅	Vermicompost 50% (2.5 t ha ⁻¹) + VAM (5 kg ha ⁻¹) + Azospirillum (2 kg ha ⁻¹) + PSB (5 kg ha ⁻¹) 50%	11.16
T ₆	Poultry manure 50% (7.5 t ha ⁻¹) + VAM (5 kg ha ⁻¹) + Azospirillum (2 kg ha ⁻¹) + PSB (5 kg ha ⁻¹) 50%	11.30
T ₇	Jeevamrutha 50% (250 l ha ⁻¹) + VAM (5 kg ha ⁻¹) + Azospirillum (2 kg ha ⁻¹) + PSB (5 kg ha ⁻¹) 50%	10.99
T ₈	Lignite 50% (0.5 MT ha ⁻¹) + VAM (5 kg ha ⁻¹) + Azospirillum (2 kg ha ⁻¹) + PSB (5 kg ha ⁻¹) 50%	9.51
T ₉	Control - FYM (25 t ha ⁻¹)	10.13
SEm (±)		0.046
CD (P=0.05)		0.138

Longitudinal curd length showed considerable variation among the treatments, with T₆ Poultry manure 50% (7.5 t ha⁻¹) + VAM (5 kg ha⁻¹) + Azospirillum (2 kg ha⁻¹) + PSB (5 kg ha⁻¹) 50% recording the maximum value (11.30 cm) which was statistically on par with T₅ (11.16 cm) followed by T₇ (10.99 cm). The minimum value was observed in T₄ (9.02 cm).

The enhanced curd length under T₆ can be attributed to improved source-sink dynamics and higher physiological efficiency under integrated nutrient management. The balanced and sustained nutrient supply likely promoted vigorous vegetative growth, leading to increased photosynthetic capacity and greater assimilate production. These assimilates were effectively mobilized and partitioned towards the developing curd, which acts as a strong sink organ, thereby contributing to

increased curd elongation. Furthermore, improved root architecture and rhizospheric activity would have enhanced nutrient and water uptake, supporting continuous metabolic processes during curd development. In addition, the combined influence of organic manures and biofertilizers may have regulated endogenous growth substances and enzyme activities involved in cell division and elongation, leading to improved curd morphology. Enhanced carbohydrate metabolism, protein synthesis and energy transfer processes also contribute to the development of larger curd structures. The overall improvement in soil health, microbial population and nutrient cycling under integrated nutrient management further supports sustained growth and development. (Kachari *et al.*, 2009)^[4].

**Fig 11:** Graphical representation on longitudinal curd length (cm)

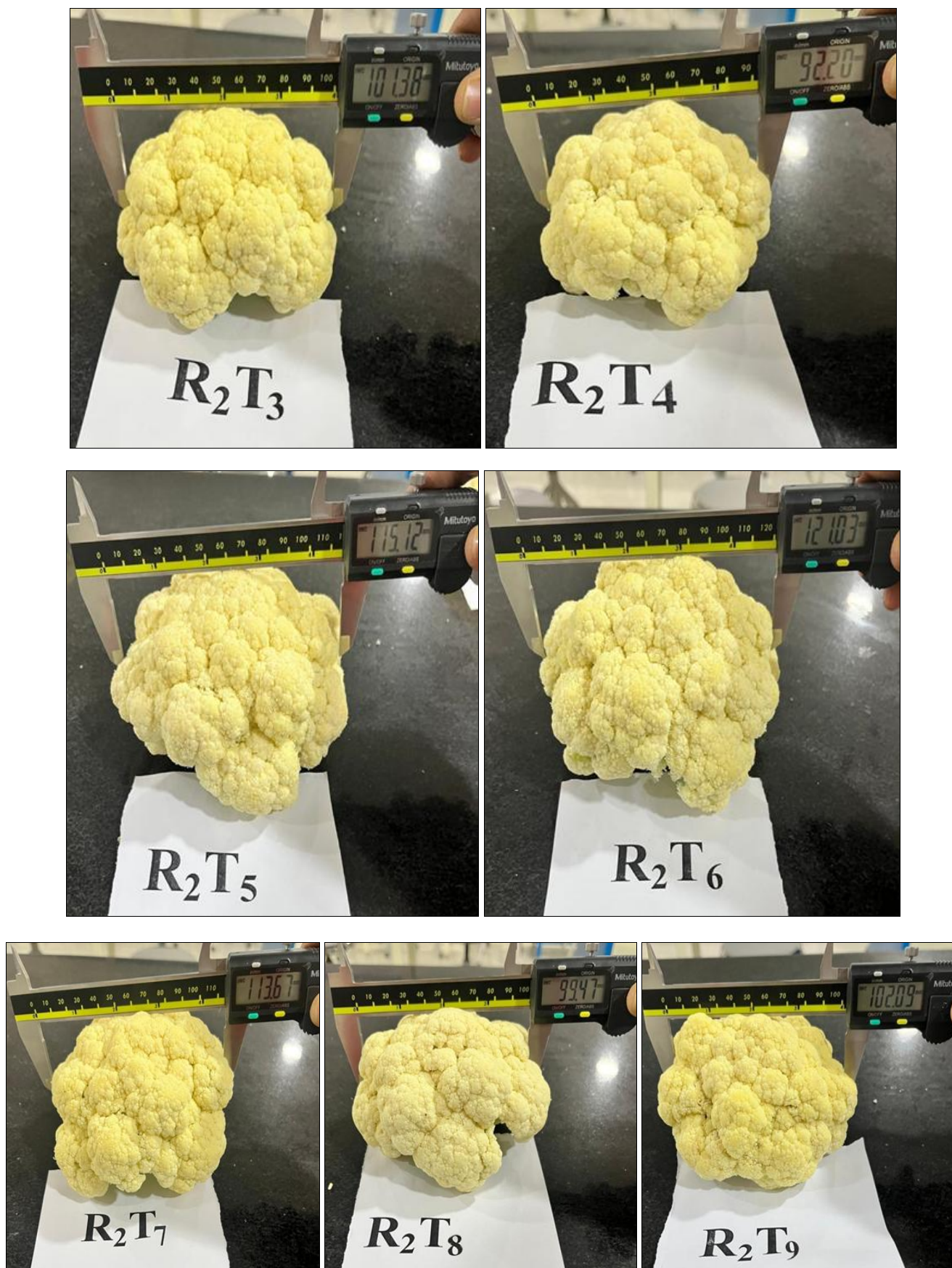


Fig 12: Measuring of longitudinal curd length (cm)

Number of days to curd initiation (days)**Table 9:** Effect of different organic manures and biofertilizers on number of days to curd initiation (days)

Treatment details		Curd initiation (days)
T ₁	Vermicompost 100% (5 t ha ⁻¹)	44.33
T ₂	Poultry manure 100% (15 t ha ⁻¹)	43.33
T ₃	Jeevamrutha 100% (500 l ha ⁻¹)	46.33
T ₄	Lignite 100% (1 t ha ⁻¹)	47.00
T ₅	Vermicompost 50% (2.5 t ha ⁻¹) + VAM (5 kg ha ⁻¹) + Azospirillum (2 kg ha ⁻¹) + PSB (5 kg ha ⁻¹) 50%	42.33
T ₆	Poultry manure 50% (7.5 t ha ⁻¹) + VAM (5 kg ha ⁻¹) + Azospirillum (2 kg ha ⁻¹) + PSB (5 kg ha ⁻¹) 50%	41.66
T ₇	Jeevamrutha 50% (250 l ha ⁻¹) + VAM (5 kg ha ⁻¹) + Azospirillum (2 kg ha ⁻¹) + PSB (5 kg ha ⁻¹) 50%	43.00
T ₈	Lignite 50% (0.5 MT ha ⁻¹) + VAM (5 kg ha ⁻¹) + Azospirillum (2 kg ha ⁻¹) + PSB (5 kg ha ⁻¹) 50%	46.66
T ₉	Control - FYM (25 t ha ⁻¹)	45.33
SEm (±)		0.354
CD (P=0.05)		1.069

The number of days to curd initiation varied significantly among the treatments, with T₆ (Poultry manure 50% (7.5 t ha⁻¹) + VAM (5 kg ha⁻¹) + Azospirillum (2 kg ha⁻¹) + PSB (5 kg ha⁻¹) 50%) recording the earliest curd initiation (41.66 days) which was statistically on par with T₅ (42.33 days) followed by T₇ (43.00 days). The maximum duration for curd initiation was observed in T₄ (Lignite 100%) with 47.00 days, respectively.

The reduced number of days to curd initiation in T₆ may be attributed to improved nutrient dynamics and enhanced physiological efficiency under integrated nutrient management. The continuous and balanced nutrient supply likely promoted rapid vegetative growth and facilitated an earlier transition from

the vegetative to reproductive phase. Improved root activity and nutrient uptake efficiency would have supported higher metabolic rates and efficient energy transfer required for curd initiation. In addition, better synthesis of growth regulators and enhanced enzymatic activity may have accelerated meristem differentiation, leading to early curd formation. Improved chlorophyll content and photosynthetic efficiency would have further supported the timely accumulation of assimilates required for initiation (Thadani *et al.*, 2019)^[12].

Number of days to curd maturation (days)**Table 10:** Effect of different organic manures and biofertilizers on number of days to curd maturation (days)

Treatment details		Curd maturation (days)
T ₁	Vermicompost 100% (5 t ha ⁻¹)	75.00
T ₂	Poultry manure 100% (15 t ha ⁻¹)	74.66
T ₃	Jeevamrutha 100% (500 l ha ⁻¹)	76.83
T ₄	Lignite 100% (1 t ha ⁻¹)	78.00
T ₅	Vermicompost 50% (2.5 t ha ⁻¹) + VAM (5 kg ha ⁻¹) + Azospirillum (2 kg ha ⁻¹) + PSB (5 kg ha ⁻¹) 50%	72.80
T ₆	Poultry manure 50% (7.5 t ha ⁻¹) + VAM (5 kg ha ⁻¹) + Azospirillum (2 kg ha ⁻¹) + PSB (5 kg ha ⁻¹) 50%	71.76
T ₇	Jeevamrutha 50% (250 l ha ⁻¹) + VAM (5 kg ha ⁻¹) + Azospirillum (2 kg ha ⁻¹) + PSB (5 kg ha ⁻¹) 50%	73.66
T ₈	Lignite 50% (0.5 MT ha ⁻¹) + VAM (5 kg ha ⁻¹) + Azospirillum (2 kg ha ⁻¹) + PSB (5 kg ha ⁻¹) 50%	77.93
T ₉	Control - FYM (25 t ha ⁻¹)	75.73
SEm (±)		0.350
CD (P=0.05)		1.058

A similar trend was observed for days to curd maturation, where T₆ recorded the earliest maturation at 71.76 days which was statistically on par with T₅ (72.80 days) followed by T₇ (73.66 days). The longest duration for curd maturation was recorded in T₄ with 78.00 days.

The earlier curd maturation observed in T₆ can be attributed to enhanced assimilate production and efficient translocation under integrated nutrient management. The balanced nutrient supply and improved soil biological activity likely supported sustained photosynthesis and faster accumulation of carbohydrates in the developing curd. Enhanced root-shoot interaction and nutrient

absorption efficiency would have contributed to better partitioning of assimilates towards the curd, enabling quicker development. Additionally, improved metabolic activity, enzyme functioning and hormonal regulation may have accelerated curd growth and compactness, resulting in early maturity. These findings are in agreement with Thakur *et al.* (2018)^[11], who reported reduced crop duration under integrated nutrient management.

Total yield (t ha⁻¹)**Table 11:** Effect of different organic manures and biofertilizers on total yield (t ha⁻¹)

Treatment details		Total yield (t/ha)
T ₁	Vermicompost 100% (5 t ha ⁻¹)	26.34
T ₂	Poultry manure 100% (15 t ha ⁻¹)	26.90
T ₃	Jeevamrutha 100% (500 l ha ⁻¹)	18.55
T ₄	Lignite 100% (1 t ha ⁻¹)	13.31
T ₅	Vermicompost 50% (2.5 t ha ⁻¹) + VAM (5 kg ha ⁻¹) + Azospirillum (2 kg ha ⁻¹) + PSB (5 kg ha ⁻¹) 50%	32.77
T ₆	Poultry manure 50% (7.5 t ha ⁻¹) + VAM (5 kg ha ⁻¹) + Azospirillum (2 kg ha ⁻¹) + PSB (5 kg ha ⁻¹) 50%	33.12
T ₇	Jeevamrutha 50% (250 l ha ⁻¹) + VAM (5 kg ha ⁻¹) + Azospirillum (2 kg ha ⁻¹) + PSB (5 kg ha ⁻¹) 50%	27.64
T ₈	Lignite 50% (0.5 MT ha ⁻¹) + VAM (5 kg ha ⁻¹) + Azospirillum (2 kg ha ⁻¹) + PSB (5 kg ha ⁻¹) 50%	13.78
T ₉	Control - FYM (25 t ha ⁻¹)	22.60
SEm (±)		1.087
CD (P=0.05)		3.287

Total curd yield of cauliflower varied markedly among the treatments, with T₆ (Poultry manure 50% (7.5 t ha⁻¹) + VAM (5 kg ha⁻¹) + Azospirillum (2 kg ha⁻¹) + PSB (5 kg ha⁻¹) 50%) recording the highest yield of 33.12 t ha⁻¹, which was statistically on par with T₅ (32.77 t ha⁻¹). The lowest yield was obtained in T₄ with 13.31 t ha⁻¹.

The enhanced yield observed in T₆ can be attributed to improved nutrient availability, uptake efficiency and better source-sink relationships under integrated nutrient management. The balanced and sustained nutrient supply likely promoted vigorous vegetative growth, leading to increased photosynthetic capacity and higher assimilate production. These assimilates were efficiently partitioned and translocated towards the curd, which acts as a strong sink, thereby contributing to increased yield.

Improved root architecture and rhizospheric activity would have further facilitated efficient nutrient and water absorption, ensuring continuous growth and development. In addition, enhanced biochemical processes such as carbohydrate metabolism, protein synthesis, and enzyme activity along with improved chlorophyll content, may have contributed to higher productivity. The integration of organic manures with biofertilizers also improves soil physical properties, microbial diversity and nutrient cycling, thereby ensuring sustained nutrient release throughout the crop growth period. These combined effects result in improved curd development, size and weight, ultimately leading to higher total yield. Similar findings were reported by Thakur *et al.* (2018) and Sharma *et al.* (2021) [6, 11].

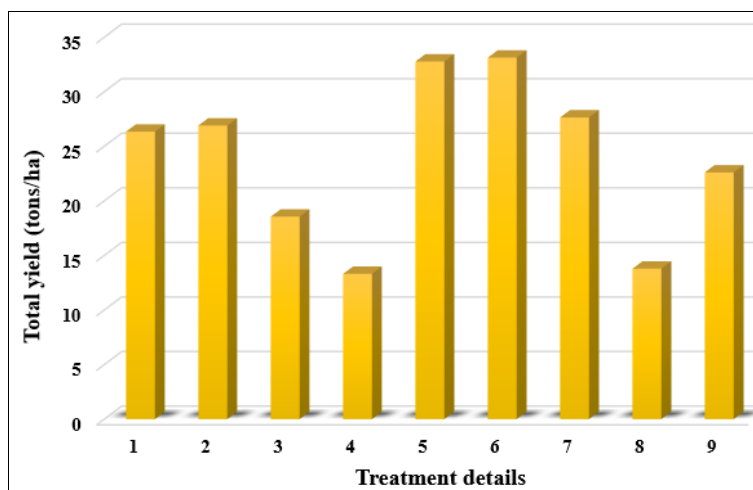


Fig 13: Graphical representation on total yield (t/ha)



Fig 14: Curd initiation, curd maturation, harvesting and yield

Conclusion

The present study clearly demonstrated that integrated application of organic manures and biofertilizers significantly improved the growth and yield of cauliflower. Among the treatments, T₆ exhibited superior performance in terms of vegetative growth, curd characteristics and yield attributes across all parameters and was closely followed by T₅. The enhanced performance of T₆ can be attributed to improved soil-plant interactions, increased microbial activity and efficient nutrient cycling under integrated nutrient management. This combination ensured a balanced and sustained nutrient supply, enhanced root architecture and rhizospheric activity and improved nutrient use efficiency. Furthermore, the integration of organic inputs with beneficial microorganisms likely enhanced physiological and biochemical processes, including chlorophyll synthesis, enzyme activity and carbohydrate metabolism, leading to higher photosynthetic efficiency and assimilate production. The effective translocation and partitioning of assimilates towards the developing curd, acting as a strong sink, contributed to improved curd formation, size and quality. Overall, the synergistic interaction between organic manures and biofertilizers created a favorable soil environment and optimized plant metabolic functions, resulting in enhanced productivity and crop performance under naturally ventilated polyhouse conditions.

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